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Smoking and asthma mediate the protective effect of educational attainment on chronic obstructive pulmonary disease risk: a mediation Mendelian randomization analysis

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Abstract

Background Clinical observational studies have shown an association between educational attainment and a lower incidence of Chronic Obstructive Pulmonary Disease (COPD). However, strong evidence for a causal relationship remains lacking.

Methods Genome-wide association data for years of schooling, cognitive performance, intelligence, COPD, and COPD-related risk factors such as smoking and asthma were obtained from public databases. We conducted two-sample Mendelian randomization (MR) analyses to assess the causal relationships between years of schooling, cognitive performance, intelligence, and the risk of developing COPD. Sensitivity analyses using MR-Egger and MR-PRESSO were performed to detect and correct for pleiotropy. Multivariable Mendelian randomization analysis was used to identify potential mediators.

Results Longer years of schooling (OR = 0.537, 95% CI: 0.474–0.608, *P* = 9.63E-23), higher cognitive performance (OR = 0.793, 95% CI: 0.702–0.895, *P* = 1.78E-04), and intelligence (OR = 0.813, 95% CI: 0.720–0.919, *P* = 8.81E-04) were causally associated with a reduced risk of COPD. Longer years of schooling were identified as an independent protective factor for COPD risk (OR = 0.600, 95% CI: 0.472 – 0.762, *P* = 2.85E-05). Smoking initiation and asthma were identified as mediating factors in the causal relationship between years of schooling and COPD risk. In the reduction of the COPD risk by years of schooling, the mediating effects of smoking initiation and asthma accounted for 32.8% and 6.9% respectively.

Conclusion These findings provide support for the causal impact of educational attainment on the occurrence of COPD, with a significant portion of this causal effect being mediated through modifiable risk factors. On the premise of controlling socioeconomic - status - related confounders, an increase in educational attainment may provide multi-

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level intervention targets for COPD prevention through intervenable pathways such as improving health behaviors and environmental exposure.

Keywords Chronic obstructive pulmonary disease, Educational attainment, Smoking, Asthma, Mendelian randomization

Introduction

Chronic obstructive pulmonary disease (COPD) is a chronic respiratory disease characterized by persistent airway obstruction and progressive decline in lung function. The pathological core of COPD lies in airway remodeling, which manifests as structural changes such as thickening of the airway walls and increased mucus secretion. These changes not only lead to airflow limitation but are also closely associated with the decline in lung function [1, 2]. Although smoking is the primary risk factor for COPD (approximately 15-20% of long-term smokers eventually develop the disease), there is significant variability in individual susceptibility, with some long-term smokers able to maintain normal lung function [3, 4].

Education, intelligence, and cognition are interconnected and inseparable; they serve as powerful predictors of socio-economic achievement and exert a wide-ranging influence on an individual's lifelong lifestyle behaviors and health resource advantages [5]. Educational level, as a core indicator of social determinants of health, has been confirmed by multiple studies to be negatively correlated with the risk of COPD. For instance, cohort studies in China have shown that individuals with less than 9 years of education have a significantly increased risk of COPD [6]. A Danish study in 2014 found that shorter education duration (< 8 years) was associated with a higher risk of COPD exacerbation and all-cause mortality [7]. It is noteworthy that individuals with lower educational levels often have higher smoking rates and an increased risk of asthma attacks, which may exacerbate the progression of COPD through direct airway damage (such as tobacco exposure) or indirect pathways (such as insufficient health management capabilities) [8, 9]. However, the existing evidence largely stems from observational studies, and their conclusions are susceptible to confounding factors (such as socioeconomic status and comorbidities) and reverse causality, making it difficult to establish a definitive causal relationship between educational level and COPD.

To address the aforementioned knowledge gap, this study employs the Mendelian Randomization (MR) approach. By utilizing genetic variants (such as single nucleotide polymorphisms, SNPs) as instrumental variables, MR mimics the logic of randomized controlled trials, effectively circumventing environmental confounders and reverse causality biases [10, 11]. For instance, genetic variants associated with educational level are randomly allocated during embryonic formation, and their association with COPD can only be mediated through the exposure factor (such as educational level), rather than being influenced by postnatal factors [12, 13]. This characteristic makes MR a powerful tool for uncovering causal relationships between social determinants and diseases.

Method

Study design

The overall study design flowchart for MR is shown in Fig. 1. Summary data for Years of Schooling (as an indicator of educational attainment), Cognitive performance, Intelligence, Smoking initiation, and Asthma were extracted from the IEU Open GWAS database (https://gwas.mrcieu.ac.uk/). Summary data for COPD were obtained from the Finngen database. Years of Schooling, Cognitive performance, and Intelligence were considered as exposure factors, Smoking initiation and Asthma were defined as mediator variables, and COPD was the outcome. SNPs were used as instrumental variables to explore the influence of Years of Schooling on COPD risk through the mediator variables, Smoking initiation, and Asthma. Inverse variance-weighted (IVW) analysis was used for both single-variable and multivariable analysis to estimate causality and the size of causal effects. We performed a two-step MR for mediation analysis. Regarding the interpretation of the results of the mediating MR analysis, in the univariate MR analysis, the effect value of the exposure on the outcome is the total effect. The effect value of the exposure on the mediator is α, and the effect value of the mediator on the outcome is β. Then the mediating effect is $\alpha \times \beta$, and the proportion of the mediating effect is $\alpha \times \beta$ / total effect. The Delta method is used to calculate the 95% confidence interval of the mediating effect.

Data sources

Summary data of GWAS for Years of Schooling, Cognitive performance, Intelligence, Smoking initiation, Asthma, and COPD were obtained from European populations. GWAS data associated with Years of Schooling (standard deviation [SD]: 4.2 years) came from the SSGAC Consortium (GWAS ID: ieu-a-1239). GWAS data related to Cognitive performance came from a GWAS study including 257,841 participants (GWAS ID: ebi-a-GCST006572). GWAS data associated with Intelligence came from a study including 269,867 participants (GWAS ID: ebi-a-GCST006250). Smoking initiation data

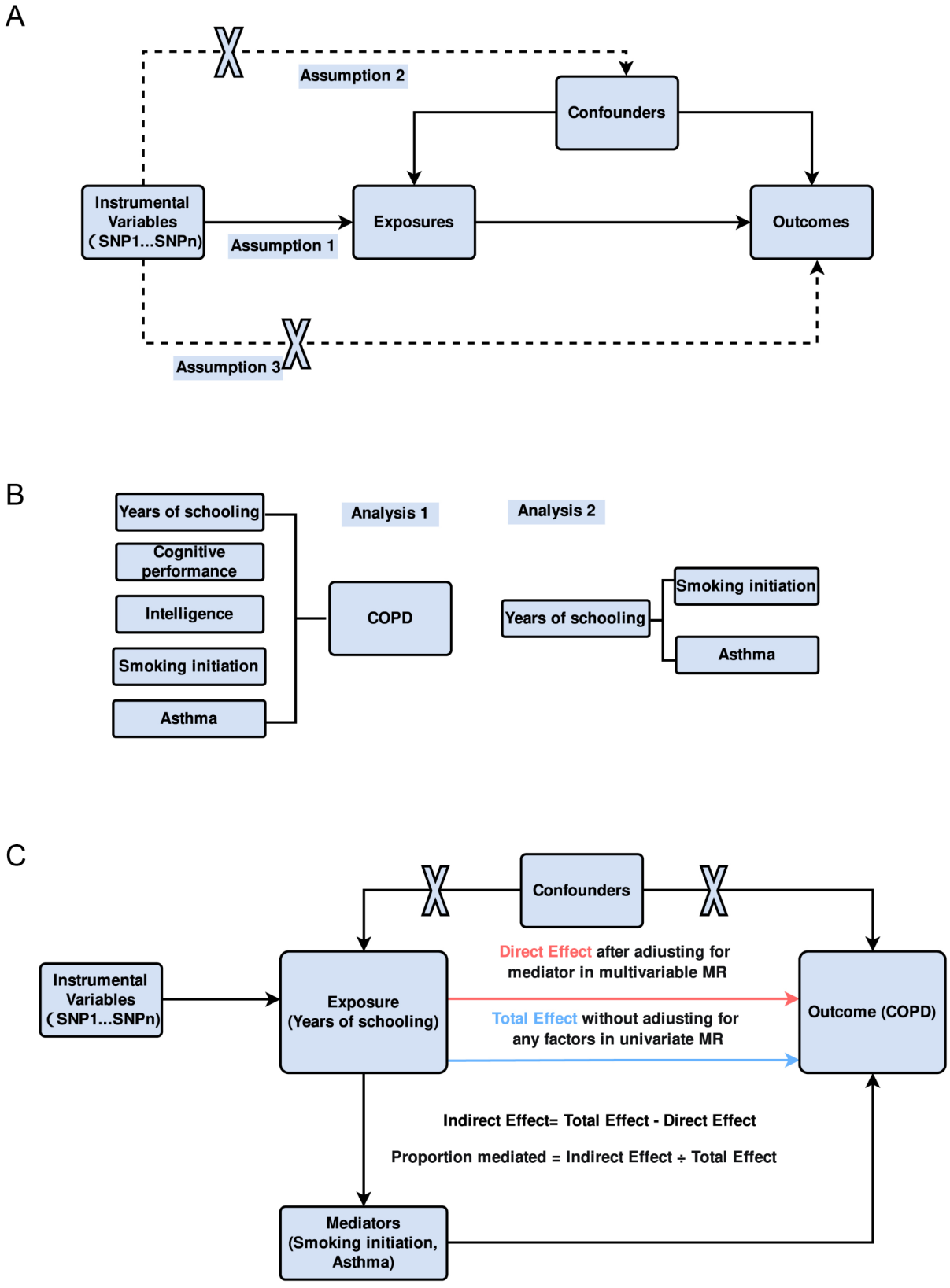

Fig. 1 Flowchart of this study. **A.** Schematic diagram of the principle of Mendelian randomization analysis. **B.** Establishment of candidate mediating factors between educational attainment and COPD using a two-step Mendelian randomization analysis **C.** Schematic diagram of the principle of mediation Mendelian randomization analysis

Table 1 Genome-wide association studies and consortium used in present study

Exposure/Outcome	Population	Participants	Data Source	Download Link
Years of schooling	European	766,345 participates	SSGAC Consortium	https://gwas.mrcieu.ac.uk/datasets/ieu-a–1239/
Cognitive performance	European	257,841 participates	IEU Open GWAS	https://gwas.mrcieu.ac.uk/datasets/ebi-a-GCST006572/
Intelligence	European	269,867 participates	IEU Open GWAS	https://gwas.mrcieu.ac.uk/datasets/ebi-a-GCST006250/
COPD	European	16,410 cases and 283,589 controls	Finngen	https://storage.googleapis.com/finngen-public-data-r8/summary_stats/finngen_R8_J10_COPD.gz
Smoking initiation	European	311,629 cases and 321,173 controls	GSCAN Consortium	https://gwas.mrcieu.ac.uk/datasets/ieu-b–4877/
Asthma	European	56,167 cases and 352,255 controls	IEU Open GWAS	https://gwas.mrcieu.ac.uk/datasets/ebi-a-GCST90014325/

were from the GSCAN Consortium, which included 311,629 cases and 321,173 controls (GWAS ID: ieu-b-4877). GWAS data for Asthma included 56,167 cases and 352,255 controls (GWAS ID: ebi-a-GCST90014325). GWAS data for COPD came from the Finngen consortium analysis, including 16,410 cases and 283,589 controls (Round 8). Detailed information for all the data is presented in Table 1.

Instrumental variable selection

SNPs were selected based on a threshold of $P < 5 \times 10^{-8}$. Subsequently, the threshold was set to $r2 < 0.001$ and $Kb > 10{,}000$ to remove linkage disequilibrium between SNPs. Palindromic SNPs were also removed from instrumental variable selection. To estimate the overall strength of selected SNPs in explaining phenotype variance, we calculated the F-statistic as follows: $F = \beta^2/SE^2$. $F > 10$ indicates that the selected SNP can significantly reduce potential bias, while $F \leq 10$ indicates a weak instrumental variable. Phenoscanner V2 was used to query and remove SNPs associated with confounding factors when COPD was the outcome (confounding factors were smoking and asthma) and when asthma was the outcome (confounding factor was smoking).

Statistical analysis

In single-variable MR analysis, five MR methods were used to examine the causal effects of exposure on outcomes, with the IVW method as the main MR strategy. MR Egger, Weighted median, Weighted mode, and Simple mode were used as supplementary methods. MR Egger, MR Pleiotropy RESidualSum and Outlier (MR-PRESSO) were used to test the heterogeneity of effects, with $P > 0.05$ indicating no effect heterogeneity. Heterogeneity analysis was performed using Cochrane Q statistics for both mr_egger and IVW, with $P > 0.05$ indicating no heterogeneity. To enhance the robustness of instrumental variables, we used the IVW_radial (alpha = 0.05, weights = 1, tol = 0.0001) function to calculate the corrected Q statistic during heterogeneity analysis and removed outlier SNPs with $P < 0.05$. Additionally, "Leave-one-out" sensitivity analysis was performed to demonstrate that individual SNPs did not affect the causal effect of exposure on the outcome. All statistical analyses were conducted using R packages "devtools," "TwoSampleMR," "LDlinkR," and "MRPRESSO." We performed 7 single-variable MR analyses, and $P < 0.00714$ (0.05/7) was considered statistically significant after multiple testing correction.

Results

Causal relationship between years of schooling, cognitive performance, intelligence, and COPD

Years of Schooling initially obtained 310 SNPs, and after harmonizing with COPD GWAS data without missing SNPs, 259 SNPs remained after removing 13 palindromic SNPs and 38 potential pleiotropic SNPs (F-statistic: 12467.25; Supplementary Table 1). Cognitive performance initially obtained 147 SNPs, and after harmonizing with COPD GWAS data without missing SNPs, 110 SNPs remained after removing 7 palindromic SNPs and 30 potential pleiotropic SNPs (F-statistic: 4759.15; Supplementary Table 1). Intelligence initially obtained 163 SNPs, and after harmonizing with COPD GWAS data without missing SNPs, 114 SNPs remained after removing 19 palindromic SNPs and 30 potential pleiotropic SNPs (F-statistic: 4954.84; Supplementary Table 1).

Single-variable IVW results showed that Years of Schooling (OR = 0.537, 95% CI: 0.474–0.608, *P* = 9.63E-23), Cognitive performance (OR = 0.793, 95% CI: 0.702–0.895, *P* = 1.78E-04), and Intelligence (OR = 0.813, 95% CI: 0.720–0.919, *P* = 8.81E-04) had a significant negative causal relationship with COPD risk (Fig. 2). Detailed MR results are presented in Supplementary Table 2. Sensitivity analysis showed that our MR analysis had no significant heterogeneity and pleiotropy (Supplementary Table 3). In the multivariable MR analysis, including Years of Schooling, Cognitive performance, and Intelligence, IVW results showed that after adjusting for Cognitive performance and Intelligence, Years of Schooling still had a negative causal relationship with COPD risk (OR = 0.600, 95% CI: 0.472 – 0.762, *P* = 2.85E-05, Fig. 3).

Mediation MR analysis

Next, we explored whether the causal effect of Years of Schooling on COPD is mediated by well-established risk factors such as Smoking initiation and Asthma. First, we analyzed the causal relationship between Years of Schooling and Smoking initiation as well as Asthma. Years of Schooling initially obtained 310 SNPs, and after harmonizing with Smoking initiation GWAS data without missing SNPs, 186 SNPs remained after removing 10 palindromic SNPs and 114 potential pleiotropic SNPs (F-statistic: 8693.19; Supplementary Table 1). After harmonizing with Asthma GWAS data without missing SNPs, 250 SNPs remained after removing 10 palindromic SNPs and 50 potential pleiotropic SNPs (F-statistic: 11940.46; Supplementary Table 1). IVW showed that Years of Schooling had a significant negative causal relationship with Smoking initiation (OR = 0.695, 95% CI: 0.666–0.726, *P* = 1.79E-59) and Asthma (OR = 0.837, 95% CI: 0.782–0.897, *P* = 4.11E-07) (Supplementary Table 2). Detailed MR results are presented in Supplementary Table 2. Sensitivity analysis showed that our MR analysis had no significant heterogeneity and pleiotropy (Supplementary Table 3).

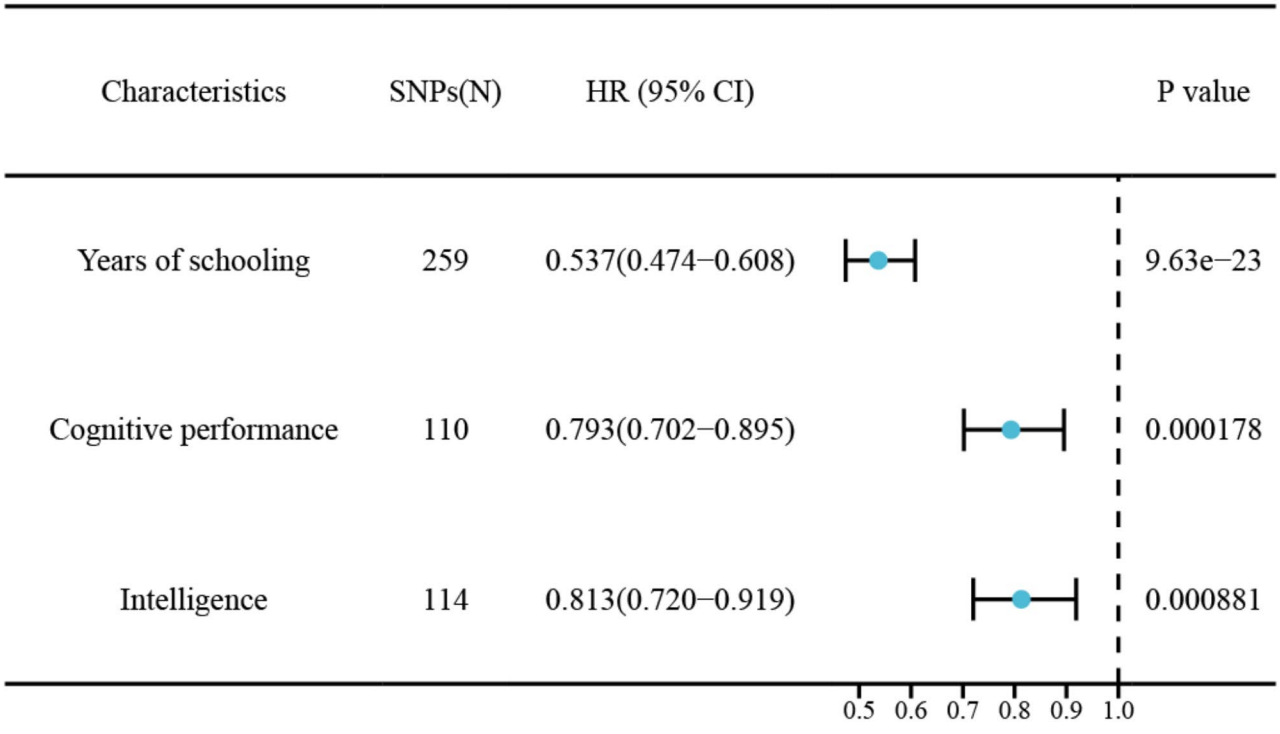

Fig. 2 Univariable MR results showing the causal effects of Years of schooling, Cognitive performance, and Intelligence on COPD

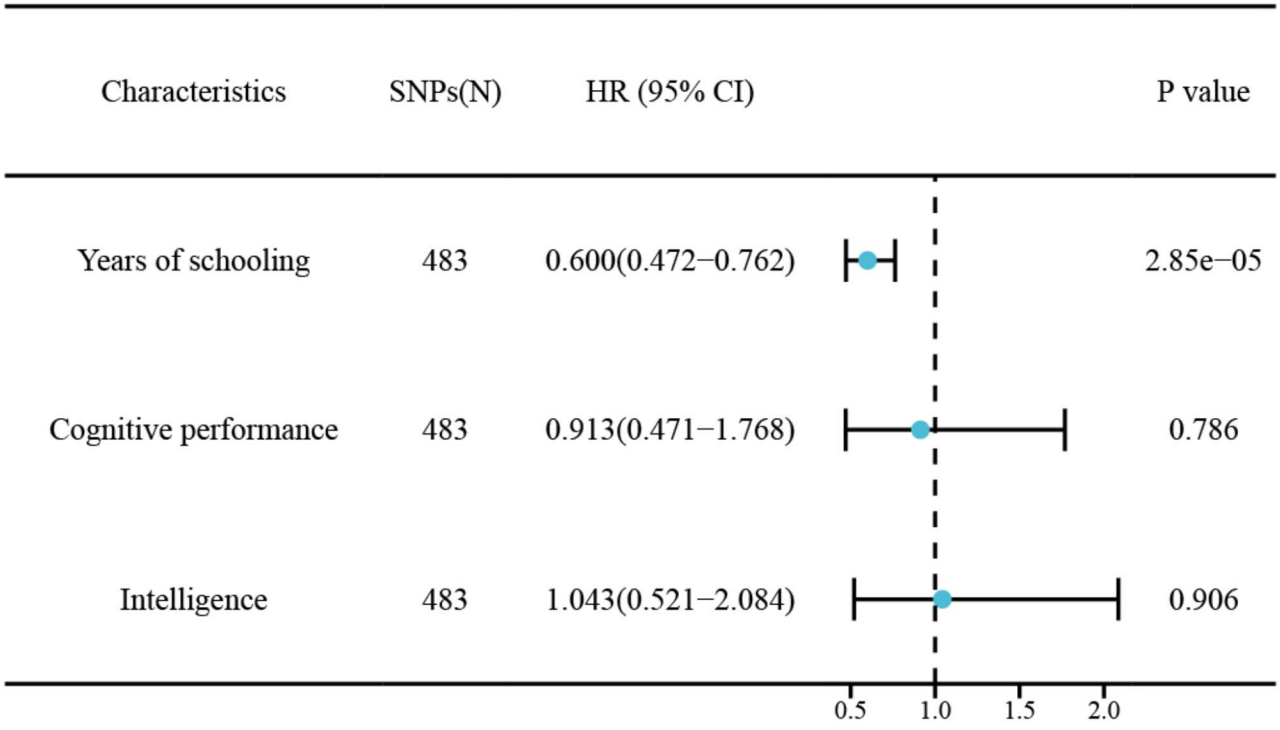

Fig. 3 Multivariable MR results showing the causal effects of Years of schooling, Cognitive performance, and Intelligence on COPD after mutual adjustment

Subsequently, we explored the causal relationship between Smoking initiation and Asthma with COPD risk. Smoking initiation initially obtained 91 SNPs, and after harmonizing with COPD GWAS data without missing SNPs, 72 SNPs remained after removing 7 palindromic SNPs and 12 potential pleiotropic SNPs (F-statistic: 8693.19; Supplementary Table 1). Asthma initially obtained 72 SNPs, and after harmonizing with COPD GWAS data without missing SNPs, 52 SNPs remained after removing 1 palindromic SNP and 19 potential pleiotropic SNPs (F-statistic: 3977.94; Supplementary Table 1). Single-variable MR analysis using IVW showed that Smoking initiation (OR = 1.754, 95% CI: 1.548–1.988, *P* = 1.25E-18) and Asthma (OR = 1.273, 95% CI: 1.203–1.347, *P* = 4.93E-17) had a significant positive causal relationship with COPD (Supplementary Table 2). Detailed MR results are presented in Supplementary Table 2. Sensitivity analysis showed that our MR analysis had no significant heterogeneity and pleiotropy (Supplementary Table 3). These results suggest that Smoking initiation and Asthma may serve as candidate mediator variables for the causal effect of Years of Schooling on COPD.

In the multivariable MR analysis, including Years of Schooling, Smoking initiation, and Asthma, the results showed that after adjusting for Smoking initiation and Asthma, the causal effect of Years of Schooling on COPD risk was attenuated (OR = 0.664, 95% CI: 0.571–0.773, *P* = 1.08E-07, Fig. 4). When using the product-method to calculate the proportion of the mediating effect of smoking, the total effect value of years of schooling on COPD is − 0.622151488045066, the effect value of years of schooling on smoking is- 0.36328531272999, and the effect value of smoking on COPD is 0.561752809854359. Therefore, the mediating effect of smoking is -0.363285 31272999 × 0.561752809854359 ≈ − 0.2041, with a 95% confidence interval of [-0.2557, -0.1525]. The proportion of the mediating effect is 32.8%, 95% CI: [22.2%, 43.4%]. The effect value of years of schooling on asthma is -0.177422067459716, and the effect value of asthma on COPD is 0.241674655565116. Therefore, the mediating effect of asthma is -0.177422067459716 × 0.241674 655565116 ≈ -0.0429, with a 95% confidence interval of [-0.0623, -0.0235]. The proportion of the mediating effect is 6.9%, 95% CI: [3.5%, 10.3%].

Discussion

Previous research has suggested that education may contribute to COPD management, as educational interventions for COPD patients have been shown to significantly improve medication adherence [14]. Furthermore, the level of education and the history of chronic respiratory diseases can influence the awareness of COPD-related knowledge [15]. Inpatient COPD education can reduce hospitalization time and related costs [16]. A cross-sectional study of Chinese COPD inpatients reported that factors such as educational attainment, average monthly income, social support, and respiratory difficulties influence the personal growth of COPD patients [17]. In

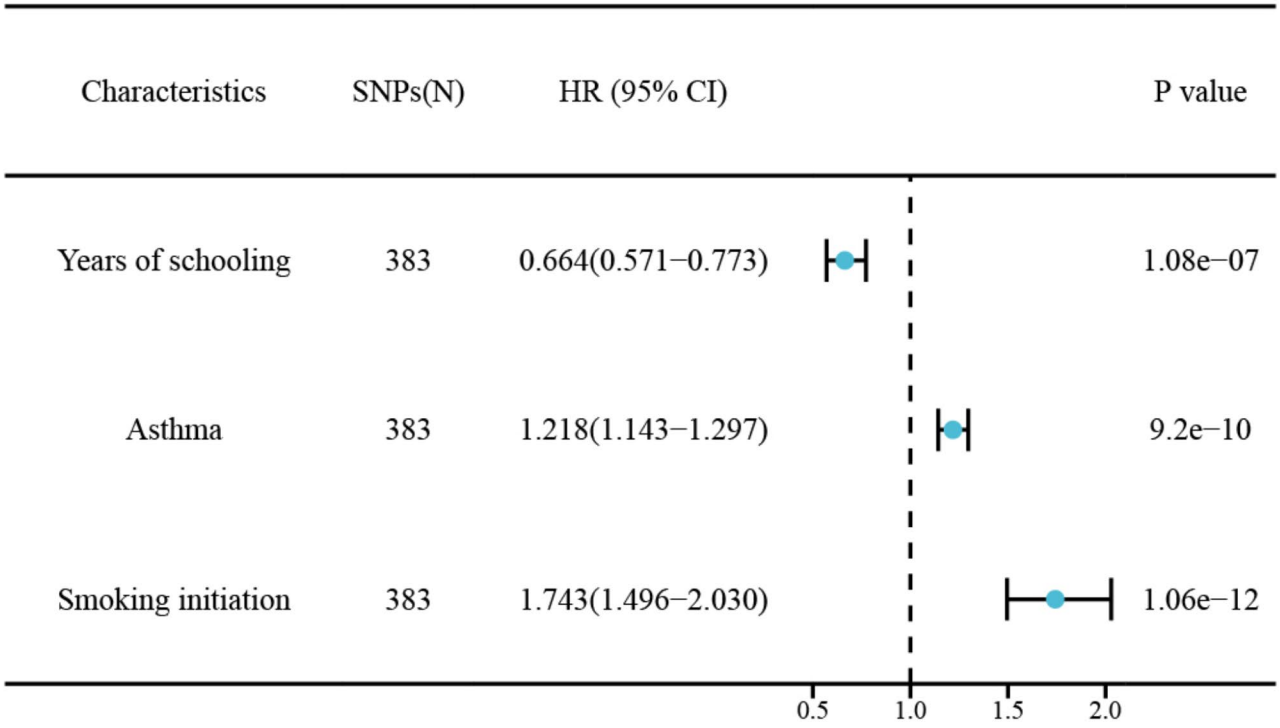

Fig. 4 Multivariable MR results showing the causal effects of Years of schooling, Asthma, and Smoking initiation on COPD after mutual adjustment

Kim's study, it was found that individuals with COPD had lower household incomes and lower baseline educational attainments compared to those without COPD, and lower educational attainment (primary school) was identified as an independent risk factor for COPD incidence [18]. The pathological process of COPD involves emphysema, and in adults with COPD, a lower level of education is associated with an increase in emphysema, possibly due to individuals tending to live in the same socio-economic group and being more exposed to tobacco smoke and particulate matter from traffic emissions, affecting normal physiological processes such as alveolar formation and development [19]. However, there has been no direct study exploring the causal relationship between educational attainment and COPD. Causality is a precious pearl on the crown of human curiosity, as it allows us to make wise choices and decisions based on an understanding of factors that may improve our quality of life [20]. We used large-scale GWAS data to support a potential protective causal relationship between educational attainment and COPD. Previous research has also reported evidence of a causal relationship between education and reduced risk of various health outcomes, including diabetes and stroke [21]. The explanation for why education may prevent COPD could be related to the broad benefits of education. For example, higher education is associated with healthier lifestyles, better working conditions, safer occupations, and improved access to healthcare [22, 23]. Education may also be related to individual decision-making abilities, leading to healthier long-term behavioral choices, making education an important factor in shaping a person's economic status, accessing social resources, and adopting healthy lifestyles throughout their lives [24, 25]. Since education has been shown to be a protective factor against COPD and is modifiable, it is recommended to extend the years of schooling to prevent COPD. While formal education is typically completed in early adulthood, from a lifelong learning perspective, educational attainment serves as an alternative indicator of knowledge acquisition, cognitive training, and health promotion opportunities in later life. Therefore, our findings provide valuable insights for prioritizing educational policies and reducing educational inequalities as effective measures to prevent the burden of COPD disease.

It is essential to determine whether traditional risk factors have a causal relationship with educational attainment and COPD or are merely bystanders. Therefore, we chose two representative modifiable risk factors (Smoking initiation and Asthma) as potential mediators from educational attainment to COPD and further conducted MR analysis. Smoking is considered a major risk factor for COPD development, and bronchial hyperreactivity is a risk factor for developing COPD [26]. In Zhao's study, 79.25% of the COPD high-risk population in China currently smoked, and nearly 73.44% were exposed to secondhand smoke [1]. A meta-analysis of Chinese adults with COPD indicated that 12 risk factors, including

smoking, low educational attainment, occupational exposure, and a family history of respiratory diseases, may increase the risk of COPD [27]. Previous observational studies consistently showed an association between lower educational achievement and increased smoking, with individuals from more disadvantaged backgrounds having higher smoking rates [28, 29]. Research has found that individuals with lower educational attainment and higher smoking rates have lower baseline Forced Expiratory Volume in 1 s (FEV1), and smoking is more prevalent in socioeconomically disadvantaged populations, with accelerated lung function decline likely related to lower socioeconomic status [30].

Observational studies can only establish associations, not causal relationships. Interestingly, previous findings indicate a causal relationship between lower educational attainments and an increased risk of smoking. One potential pathway through which educational attainment influences health is through health behaviors like smoking. Higher educational attainments are associated with a lower likelihood of individuals starting to smoke, milder smoking addiction among smokers, and a higher likelihood of quitting smoking [31].A study assessing smoking cessation treatment among Chinese COPD patients reported that patients with higher educational attainments, stronger self-efficacy, and better readiness to quit smoking were more likely to adhere to smoking cessation treatment [32]. Increasing educational attainments can effectively improve smoking cessation outcomes. Asthma is a long-term chronic inflammatory disease of the airways. Chronic inflammation is associated with airway hyperresponsiveness, leading to recurrent episodes of wheezing, dyspnea, chest tightness, and/or cough that may vary over time [33]. The progression of asthma severity and the overlap of symptoms observed in some asthma and COPD patients suggest that asthma may be a risk factor for the subsequent development of COPD [34]. Several studies have identified early exposures, such as childhood asthma and respiratory problems, as risk factors for COPD [35]. Recent epidemiological research suggests that asthma patients may have an increased risk of developing COPD, regardless of smoking history [36]. A recent meta-analysis found that patients with a history of asthma had a 7.87-fold increased likelihood of developing COPD in later life after controlling for relevant confounding factors [37].There is a significant association between lower educational attainments, asthma, and COPD; lower educational attainments are more likely to lead to asthma and also promote the progression of asthma to COPD. In a study quantifying the risk of COPD in women with asthma, lower educational attainments, high body mass index, rural residence, and increased smoking levels were associated with an increased risk of COPD incidence [38]. Another study showed that a low socioeconomic status based on education and family income was associated with the prevalence of asthma and COPD among adults [39]. Compared to individuals with higher educational attainments, asthma patients with only primary education had an increased risk of uncontrolled asthma, and educational attainment was more crucial for asthma control in patients with persistent or severe asthma [40]. This could be attributed to better compliance after receiving education, leading to a better understanding of proper asthma medication use and daily care, resulting in improved disease control and prognosis. Additionally, studies have indicated that individuals with lower educational attainments have a higher risk of work-related asthma. This connection may be a result of workplace environmental exposure. Lower educational attainments may be associated with lower professional qualifications, limiting job choices, making individuals more likely to work in high-risk environments. Another explanation is that economically disadvantaged patients may have to work at an early age instead of attending school, and with increasing exposure time, the risk of work-related diseases also increases [41]. Our analysis also found a significant negative causal relationship between smoking initiation and asthma and educational attainment, and a significant positive causal relationship between these factors and COPD, suggesting a potential mediating role of asthma in the association between educational attainment and COPD. As a preventable and treatable disease, improving educational attainment, effectively controlling asthma, and enhancing smoking cessation outcomes can reduce the medical burden of COPD and improve global health. Our analysis also revealed a significant negative causal relationship between smoking initiation, asthma, and educational attainment, as well as a significant positive causal relationship between these factors and COPD. Therefore, it is considered that asthma may serve as a potential mediator between educational attainment and COPD. COPD, as a preventable and treatable disease, can benefit from improvements in educational attainment, effective asthma control, and enhanced smoking cessation outcomes, leading to a reduction in the medical burden of COPD and an improvement in global health.

The advantages of using MR analysis lie in the fact that genetic determinants of risk factors occur before the onset of the disease, which helps to avoid potential biases in reverse causation that can occur in retrospective studies and reduces the risk of confounding. However, this study has several limitations. Firstly, although asthma and smoking explain to a large extent the impact of educational attainment on COPD risk, there are still other mediators that need to be further explored. This method cannot completely block the impact of educational inequality on COPD. Second, due to the limited sample size of GWAS of non-European ancestries (such as

African and East Asian) in the current public databases, we were unable to conduct cross-ancestry Meta-analysis or stratified subgroup analysis. This data gap limits the external validity of the conclusions and fails to rule out the potential impact of ancestry-specific confounding factors (such as differences in environmental exposures or variations in allele frequencies) on the mediating pathways. Future research should prioritize addressing the issue of insufficient diversity in genetic data. For example, multi-ancestry collaborative alliances should be established to share standardized phenotypic and genotypic data. Transfer learning or cross - ancestry polygenic risk score (PRS) methods should be applied to improve the analysis efficiency of small - sample ancestries. Through the longitudinal design of Mendelian randomization, the environmental confounding related to ancestry and the genetic causal effects should be separated. Thirdly, considering the limitations of GWAS summary data, there was no stratified analysis based on population characteristics such as gender and age. Subsequently, although the strength of the instrumental variables decreased after excluding SNPs, the two-stage average F-statistic was still higher than the weak-instrument threshold (F = 10). Moreover, the results of the sensitivity analyses (weighted median, MR-Egger) were consistent with those of the main analysis, suggesting a low risk of weak-instrument bias. However, future research needs to further optimize the selection of instrumental variables through larger-sample GWAS or functional validation. Finally, given the limitations of MR analysis, we cannot completely avoid reverse causality.

Conclusion

In conclusion, our study suggests that higher educational attainments are associated with a reduced incidence of COPD, and there may be a protective causal relationship between educational attainment and COPD.

Abbreviations

COPD	Chronic Obstructive Pulmonary Disease
CI	Confidence Interval
FEV1	Forced Expiratory Volume in 1 s
GWAS	Genome-wide Association Studies
IVW	Inverse Variance-Weighted
MR	Mendelian Randomization
OR	Odds Ratio
SD	Standard Deviation
SNP	Single Nucleotide Polymorphism

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12890-025-03658-1.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

Xue Bai led the research, conducted data analysis, and drafted the manuscript; Lantao Chen, Fenghai Ren, and Ying Zhao analyzed the data and prepared the figures; Yue Zheng and Yanbo Wang revised the manuscript; Sainan Pang, Jian Zhang, and Erliang Guo conducted language editing; Huiyan Li supervised the entire study.

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Data availability

The download link for the GWAS summary data used in this study is as follows: Years of schooling: https://gwas.mrcieu.ac.uk/datasets/ieu-a-1239/. Cognitive performance: https://gwas.mrcieu.ac.uk/datasets/ebi-a-GCST006572/. Intelligence: https://gwas.mrcieu.ac.uk/datasets/ebi-a-GCST006250/. COPD: https://storage.googleapis.com/finngen-public-data-r8/summary_stats/finngen_R8_J10_COPD.gz. Smoking initiation: https://gwas.mrcieu.ac.uk/datasets/ieu-b-4877/. Asthma: https://gwas.mrcieu.ac.uk/datasets/ebi-a-GCST90014325/

Declarations

Ethics approval and consent to participate

The data used in this study is publicly available, therefore further ethical approval is not required.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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